

Chapter 6: Residential Lighting Evaluation Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

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**Subcontract Report
NREL/SR-7A30-53827
February 2014**

Chapter 6 – Table of Contents

1	Measure Description	2
2	Application Conditions of Protocol	3
3	Savings Calculations	4
4	Measurement and Verification Plan.....	5
4.1	Number of Measures Sold or Distributed	5
4.2	Delta Watts.....	6
4.3	Approaches for Estimating Baseline Wattage	6
4.4	Recommended Approach.....	10
4.5	Replacement of Efficient-Lighting Products With Newer Efficient-Lighting Products	13
4.6	Uncertainty Regarding the Baseline and the Need for Ongoing Research	14
4.7	Annual Operating Hours	15
4.8	Metered Data Collection Method.....	17
4.9	Using Secondary Data.....	20
4.10	Snapback/Rebound or Conservation Effect	21
4.11	In-Service Rate.....	21
4.12	Interactive Effects With Heating, Ventilating, and Cooling.....	24
5	Other Evaluation Issues	26
5.1	Cross-Customer Class Sales	26
5.2	Cross-Service Area Sales (Leakage).....	27
5.3	Estimating Cross-Customer Class and Cross-Service Area Sales	27
6	Program Evaluation Elements.....	29
7	References.....	30
8	Resources	32

List of Tables

Table 1. Strengths and Limitations of Alternative Delta Watts Estimation Approaches	8
Table 2. Standard Lamp Estimated Baseline Wattage for Lumen Equivalencies	12
Table 3. Specialty Lamp Estimated Baseline Wattage for Lumen Equivalencies.....	13
Table 4. Estimated CFL Hours of Use from Recent Metering Studies	16
Table 5. Estimated First-Year, In-Service Rates from Recent Evaluations of CFL Upstream Lighting Programs	22
Table 6. Estimated Three-Year In-Service Rate Calculations	24

1 Measure Description

In recent years, residential lighting has represented a significant share of ratepayer-funded energy-efficiency electricity savings. Utilities have achieved the majority of these savings by promoting the purchase and installation of compact fluorescent lamps (CFLs), both standard “twister” bulbs and specialty CFLs such as reflectors, A-Lamps, globes, and dimmable lights. Some energy-efficiency programs have also promoted ENERGY STAR[®] lighting fixtures, and recent programs have introduced solid-state light-emitting diode lamps (LEDs).

Due to the provisions of the 2007 Energy Independence and Security Act (EISA), the accuracy of the savings claims from residential lighting programs remains uncertain. This legislation requires that during the period from 2012 through 2014, the energy efficiency of most types of screw-based light bulbs improves by approximately 28%, as measured by the efficacy in units of lumens per watt (W).

EISA requirements take effect in phases, beginning with 100-W equivalents in 2012, 75-W equivalents in 2013, and 60-W and 40-W equivalents in 2014. Additionally, there is a “backstop” provision in the legislation, ensuring that the previous EISA requirements produce savings equal to or greater than an efficiency standard of 45 lumens per watt. If this goal has not been achieved by 2020¹, then legislation will prohibit the sale of any general service lamp² that does not meet the minimum efficiency standard.

Since EISA took effect in 2012, many lighting efficiency programs have continued to reap significant savings, but evaluating these programs has become increasingly complex. Thus, this evaluation protocol was updated in 2014 to resolve some evaluation uncertainties affecting residential lighting incentive programs. These uncertainties include: sell-through periods of EISA affected bulbs, questions regarding EISA exemptions, and how the EISA 2020 backstop provision affects savings estimates.³ In addition, this revised version updates other research topics—such as protocols for estimating hours of use and in-service rates—based on recent research.

¹ In California, the backstop provision takes effect in 2019

² EISA defines a general service lamp as one that (1) is intended for a general service or general illumination application (whether incandescent or not); (2) has a screw base; and (3) is capable of being operated at a voltage at least partially within the range of 110 to 130.

³ The first version of the UMP Residential Lighting Evaluation Protocol was finalized in April 2013.

2 Application Conditions of Protocol

Residential lighting measures are typically delivered by program administrators through these four mechanisms.

- ***Upstream Buy-Down/Mark-Down.*** The most common approach to achieve residential lighting savings is offering “upstream” incentives to manufacturers (buy-down) or retailers (mark down) that reduce the cost of CFLs and LEDs for consumers. Because this delivery mechanism offers the discount at the time of purchase (that is, at the point of sale), the end-user customers are not required to complete an application or any paperwork.
- ***Direct Install.*** Many program administrators who offer residential audit programs include as a program feature the direct installation of CFLs or LEDs at the time of an audit. Most programs offer audits at either no cost or at a highly discounted cost to the customer, and there is usually no additional cost for the installed bulbs.
- ***Giveaways.*** A number of program administrators have provided CFLs free of charge to residential customers through the mail, at customer service offices, or at events organized by community or religious organizations or by local government agencies. In some programs, the CFLs are mailed to customers only upon request. In other programs, the CFLs are distributed without prior customer request. The amount of customer information collected at the time of giveaway events varies, with some program administrators requiring full name and contact information and other program administrators not requiring any.
- ***Coupons.*** Some program administrators have relied on instant (point-of-sale) or mail-in coupons as the incentive mechanism for residential lighting products. These coupons typically require that customers provide their name and contact information to obtain the product at the discounted price or to receive the rebate.

Although this Residential Lighting Evaluation Protocol applies to all of these delivery mechanisms, the strategies for collecting and analyzing the data necessary to calculate the savings tend to vary. This protocol highlights and provides details regarding the different strategies and approaches to data collection and analysis.

Also, program administrators may need to prioritize their evaluation resources regarding particular combinations of measures and delivery strategies, based on criteria such as the contribution to savings and the assessed uncertainty of those savings estimates. (For example, uncertainty can occur with programs that have not been evaluated for a while or that have shifting baselines.)

3 Savings Calculations⁴

While evaluators can calculate gross energy first-year energy savings from residential lighting measures through a number of algorithms, this protocol recommends the following general algorithm:

Equation 1

$$\text{kWh}_{\text{saved}} = \text{NUMMEAS} * (\Delta W / 1,000) * \text{HRS} * \text{ISR} * \text{IE}_e$$

where:

$\text{kWh}_{\text{saved}}$ =first-year electricity savings measured in kilowatt-hours

NUMMEAS =number of measures sold or distributed through the program

ΔW =delta watts (baseline wattage minus efficient lighting product wattage)

HRS =annual operating hours

ISR =in-service rate

IE_e =cooling and heating interactive effects

This chapter covers the recommended techniques for estimating each of these parameters, based on either primary or secondary data.

⁴ As presented in the Introduction chapter, the methods focus on energy savings and do not include other parameter assessments such as net-to-gross, peak coincidence factor (or demand savings), incremental cost, or measure life.

4 Measurement and Verification Plan

Evaluators should calculate the savings from residential lighting measures through a mix of measured and estimated parameters. This protocol recommends this approach, which is similar to Option A of the International Performance Measurement and Verification Protocol (IPMVP), because the values for some parameters can be directly measured through metering (such as annual hours of use). However, evaluators should estimate others parameters (such as delta watts for upstream lighting programs) through other techniques.

4.1 Number of Measures Sold or Distributed

The administrator (or a third-party implementation contractor) should track the number of measures sold or distributed through a program and compile this information in a database that contains as much detail as possible regarding the measures delivered. For example, the detailed information for each transaction in an upstream program should include the following:

- Product shipment dates from manufacturer to retailer, where applicable
- Detailed product information such as:
 - Bulb type (CFL, LED)
 - Wattage
 - Style and features (twister, reflector, A-Lamp, globe, dimmable)
 - Manufacturer and product identifier (UPC or SKU codes)
 - Rated lumens
 - Date of retail sale, if available
- Number of products incented (number of packs and bulbs per pack)
- Date incentive paid
- Dollar value of incentives paid
- Location where products were sold (including retailer name, address, city, state, and ZIP code)
- Final retail sales price of product, if available
- Company contact information (store manager or corporate contact name and phone number)
- Assumptions regarding any parameters to savings estimates.

For programs using other delivery strategies, administrators should collect similar details. For example:

- Information collected for an audit program would include the numbers and types of products installed, the wattage of the replaced bulb and location (room type), the date of installation, and contact information.

- Data collected for giveaway programs should contain at least the customer contact information, the quantity/type of product given away, and the detailed product information previously listed.

At a minimum, the evaluation should include a basic verification of savings, whereby the evaluator (1) sums up the detailed transactions and (2) attempts to replicate the calculation of total claimed savings for the specific time period in which the savings were claimed, such as a program year or cycle.

Evaluators should treat discrepancies between claimed and verified number of measures as adjustments to the number of program measures. In other words, if the *total* number of measures distributed does not match the number of measures claimed by a program administrator, the evaluator should adjust the number of measures assumed sold or distributed accordingly. (That is, if the number of measures claimed by a program administrator does not match what is in the detailed tracking data, then the evaluator should regard the amount noted in the tracking data as the correct number.)

4.2 Delta Watts

The difference between the wattage of the efficient lighting measure and the wattage of the assumed baseline measure is the delta watts. As noted, administrators should enter the wattage of the efficient measure in the program tracking database.

Where possible—such as with direct install programs—the implementation contractor should record the wattage of the particular lamp that the program measure replaces.⁵ Typically, this is done at the time of the audit, when auditors replace the existing measure with the efficient measure. However, this is not possible for most program delivery strategies, so evaluators often need to estimate baseline wattage. In addition, the baseline assumptions need to incorporate the transition to EISA standards that began in 2012.

4.3 Approaches for Estimating Baseline Wattage

Recent studies have used these approaches for estimating baseline wattage.

- ***Self-Report.*** Evaluators use customer surveys conducted after the installation to collect information about the wattage that consumers used before installation of the energy-efficient lighting.
- ***In-Home Inspections to Examine Wattage of Equivalent Fixtures.*** The implementation contractor examines the labeled wattage of bulbs in similar fixtures in each home to estimate the wattage the consumer used before installation of the energy-efficient lighting.

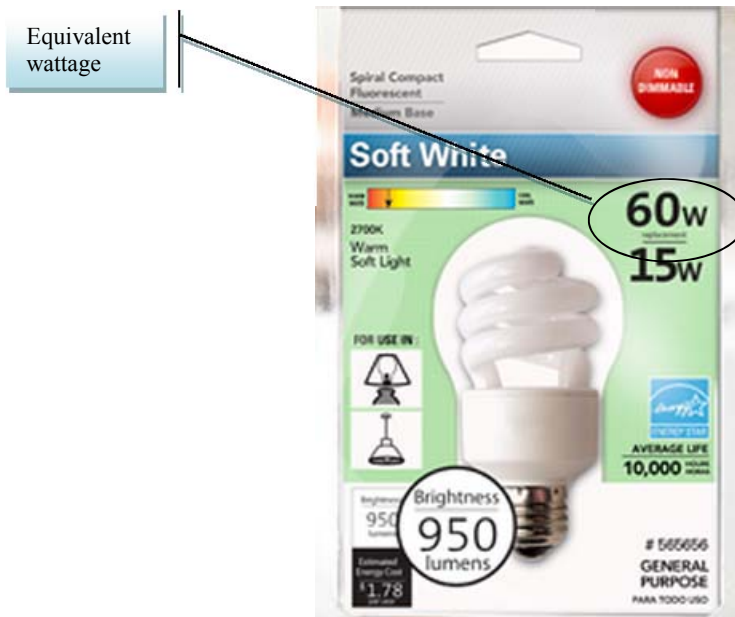
⁵ Note, however, that the baseline lamp typically has a much shorter lifetime than the retrofit lamp and the baseline may shift over the life of the retrofit lamp (particularly due to EISA).

- ***Multipliers.*** Evaluators assume the baseline to be a multiple— for example, three or four times the wattage—of the efficient measure; thus, the evaluator will use one value (a single multiplier) across all program bulbs.
- ***Lumen Equivalence.*** EISA standards require that lumen ranges and assumptions regarding the equivalent wattage of incandescent lights be specified on all retail lamp packaging (see Figure 1).
- ***ENERGY STAR Lumen Equivalence (Manufacturer Rating).*** Most energy-efficient lighting products prominently list the replacement wattage assumptions on the box (see Figure 1), and ENERGY STAR guidelines require these bulbs use specific baseline wattages based on lumen bins.⁶ The Energy Labeling Rule⁷ requires manufacturers to include detailed information regarding lamp output and efficacy as part of the “Lighting Facts” label now required.

⁶ ENERGY STAR Lamps V1.0 requires a standard manufacturer baseline rating scale based on brightness (lumens) and bulb shape. Detailed specifications are available online at: https://www.energystar.gov/products/specs/lamps_specification_version_1_0_pd

⁷ Information about this rule is available online at: <http://www.business.ftc.gov/documents/bus26-lighting-facts-questions-and-answers-manufacturers>

Figure 1. Example of Manufacturer Rated Baseline Wattage⁸



Error! Reference source not found. lists the strengths and limitations of each of these approaches.

Table 1. Strengths and Limitations of Alternative Delta Watts Estimation Approaches

Approach for Estimating Baseline Wattage	Strengths	Limitations	Recent Studies Using Approach	Estimated Incandescent to CFL Ratio ⁹
Customer self-report	Captures customer intentions and bin shifting.	Potentially low recall and social desirability bias.	Duke Energy Residential Lighting Program (2010)	4.25
Examining equivalent fixtures	Actual recording of baseline wattage for existing measures.	Difficult to identify equivalent fixtures and high cost to conduct statistically representative on-site study.	California Upstream CFL Program (2006-2008)	3.6

⁸ Information about this rule is available online at:
http://www.energystar.gov/index.cfm?c=cfls.pr_cfls_lumens

⁹ The incandescent-to-CFL wattage will vary, based on both the types of bulbs promoted (for example, standard vs. specialty) and the typical CFL wattage for a particular program. In addition, evaluators will sometimes show this ratio as the ratio of the delta watts to CFL. (For example, the Mid-Atlantic TRM recommends a delta watts-to-incandescent ratio of 2.95).

Approach for Estimating Baseline Wattage	Strengths	Limitations	Recent Studies Using Approach	Estimated Incandescent to CFL Ratio ⁹
Standard multipliers	Low effort and low cost. Accuracy derived from empirical program data and, perhaps, better funded studies.	Determining the appropriate multiplier for the program is difficult without basing it on another approach, or relying on other studies. The resulting estimate can be biased depending on the distribution of bulb type and wattages.	Mid-Atlantic Technical Reference Manual (TRM) / Vermont Energy Investment Corporation (2011) Ohio TRM / Vermont Energy Investment Corporation (2010)	3.95 4.25
ENERGY STAR lumen equivalence (Manufacturer rated baseline wattage)	Widely available, relatively inexpensive to implement. Data based off of wattage rating on package, which is often prominently displayed on the product. Approach is consistent with ES v1.0 specification.	May not match the EISA lumen bins or not adjusted for EISA (i.e., uses legacy bulb wattages).	Wisconsin Focus on Energy Residential Lighting Program (2007)	4.0
EISA Lumen equivalence	Widely available, relatively inexpensive to implement. In some cases, matches the marketed baseline wattage or matches up with EISA standards.	May provide conservative estimate in cases where marketed baseline wattage exceeds rated lumen output.	Commonwealth Edison PY3 Residential Lighting Program (2012)	N/A

Further complicating the assessment of baseline wattage is the fact that the lumen equivalency bins for EISA legislation do not align with the ENERGY STAR lumen bins. This inconsistency results in EISA baselines varying from what is noted on bulb packaging (see Figure 2**Error! Reference source not found.**).

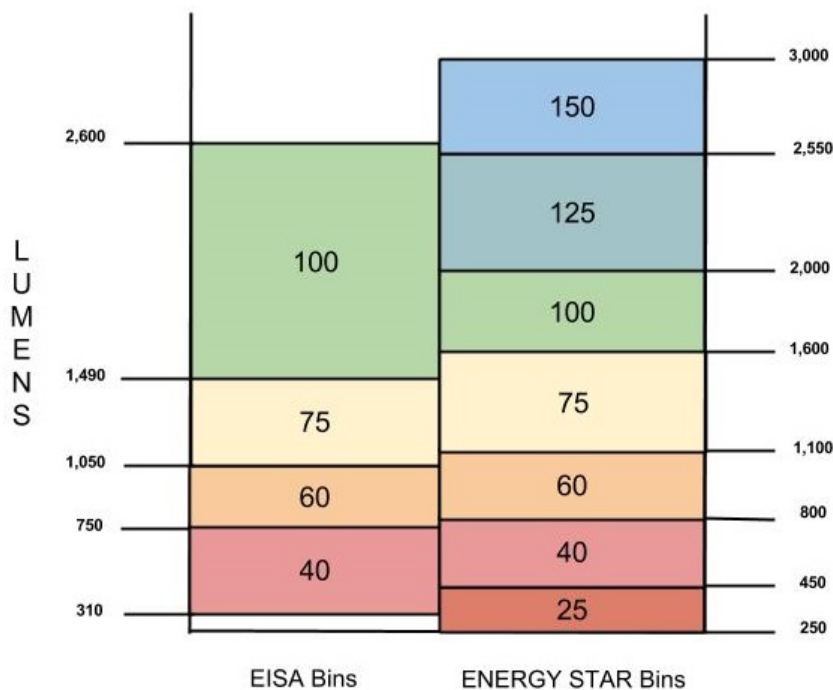


Figure 2. Baseline Wattage by Lumens, EISA vs ENERGY STAR¹⁰

4.4 Recommended Approach

Consumers are more likely to purchase bulbs based on the rated baseline wattage rather than the lumens.¹¹ Thus, for direct-install programs, the implementation contractor should collect baseline wattage information at the time of measure installation. Where baseline information cannot be collected, the Residential Lighting Evaluation Protocol recommends using an adjusted ENERGY STAR lumen equivalency rating (manufacturer rated baseline wattage) and then adjusting these estimates for the EISA requirements. The protocol recommends this approach because the manufacturers' rated baseline wattage for ENERGY STAR bulb must be based on ENERGY

¹⁰ EISA bins are provided in the legislation online at: http://www.lightopedia.com/_files/eisa/energy-independence-and-security-act-of-2007.pdf and ENERGY STAR bins are provided in the ENERGY STAR Lamp Specifications online at: https://www.energystar.gov/products/specs/lamps_specification_version_1_0_pd

¹¹ Recent studies have shown that consumers are still largely unaware of lumens. For example, a forthcoming study from New York found that only 57% of respondents had even heard of the term lumens and, of those, more than 80% could not say how many lumens a 60-W bulb uses.

STAR lumen categories. This approach incorporates EISA requirements, which are based on lumen output.

In addition, recent research indicates that there may be significant “sell through” of existing product during the phase-in years.^{12,13,14} As a conservative estimate, the Residential Lighting Evaluation Protocol recommends using the new baseline values only after each phase-in of the legislation has been in effect for six months. (See an alternative approach in the *Uncertainty Regarding the Baseline and the Need for Ongoing Research* section later in this chapter).

Alternatively, for studies that have sufficient budget to screen for a statistical sample of recent CFL purchasers, evaluators may use the self-report approach to estimate delta watts (as well as other purchase attributes including location and price). The Residential Lighting Evaluation Protocol recommends, however, that the consumer recall approach apply these time limits (from the time the consumer purchased the bulb):

- A maximum of a six-month window (and preferably a three-month window) for standard spiral CFLs.
- Up to a year for specialty CFLs and LEDs, as these have far lower purchase incidence but represent larger purchase decisions.

When consumers do not replace bulbs with the same comparable wattage as the previous bulb, this is called “bin shifting.” An example of this is when a consumer replaces a 60-W bulb with a 75-W equivalent. Consumers can bin shift to higher- or lower-than-expected wattages. Note that the self-report approach offers the advantage of capturing consumer “bin shifting,” although there is little evidence that consumers “bin shift” when purchasing CFLs.^{15,16}

Since EISA legislation does not apply to a number of bulb types, so as the first step in determining baseline wattage, evaluators need to establish whether a bulb is exempt from EISA

¹² The PY2012 Duke Energy Progress *Shelf-Stocking Study Results for the Residential ENERGY STAR Lighting Program* found that 55 of 70 stores visited had at least one phased-out bulb six months after EISA implementation date. These non-compliant bulbs were found in all retail channels.

¹³ The *Residential Lighting Shelf Survey and Pricing Analysis (June 8, 2013)*, by The Cadmus Group and NMR also found significant amounts of EISA phased-out bulbs after the EISA implementation dates.

¹⁴ At the time of this protocol, all of the EISA lighting requirements were implemented except for the 2020 backstop provision. These sell-through periods are applicable for evaluating 2013 and 2014 lighting programs.

¹⁵ For example, the evaluation of the PY2011-PY2012 Duke Energy Progress Lighting Program found that only 2.6% of purchased CFLs might have been a different equivalent wattage than the incandescent bulbs they replaced.

requirements. To do this, evaluators need classify bulbs by shape, base type, lumens, and specialty features. Commonly used EISA-exempt bulbs include:

- 3-way bulbs
- Globes with $\geq 5''$ diameter or ≤ 749 lumens
- Candelabra base bulbs with ≤ 1049 lumens^{17,18}

The baselines for exempt bulbs should match the manufacturer-rated wattage (Column C in Table 2 and Table 3).

When synchronizing evaluated baselines to those noted on bulb packaging, it is important to be aware that the recommended lumen equivalencies differ for standard and specialty bulb shapes, in line with ENERGY STAR labeling requirements. Table 2 provides the assumed baseline wattage based on lumen range for standard lamps (medium screw-base bulbs that are not globe, bullet, candle, flood, reflector, or decorative shaped). Evaluators can use the manufacturer recommended baseline wattage for bulbs with lumens outside of the lumen values shown in the table. Baselines in Table 2 apply to twist/spiral and A-lamp shaped bulbs and incorporate EISA phase-in periods through 2014.

Table 2. Standard Lamp Estimated Baseline Wattage for Lumen Equivalencies

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Wattage	
		Baseline (Exempt Bulbs) (c)	Baseline (Post-EISA) (d)
2,000	2,600	150	72
1,600	1,999	100	72
1,100	1,599	75	53
800	1,099	60	43
450	799	40	29
310	449	25	25

Table 3 provides the assumed baseline wattage—based on lumen range—for specialty and decorative shaped lamps. Evaluators can use manufacturer recommended baseline wattage for bulbs with lumens outside of the lumen values shown in Table 3. Specialty lamps are medium

¹⁷ See EISA legislation for the full list of exemptions.

¹⁸ Flood and reflector lamps have separate EISA requirements that took effect in July 2012. The flood/reflector specific lumen per watt requirements should be used as the baseline for any program equivalent lamps.

screw-base bulbs that are globe, bullet, candle, or decorative shaped.¹⁹ Baselines in Table 3 incorporate EISA requirements.

Table 3. Specialty Lamp Estimated Baseline Wattage for Lumen Equivalencies

Lumen Bins		Incandescent Equivalent Wattage	
Decorative Shape (a)	Globe Shape (b)	Baseline (Exempt Bulbs) (c)	Baseline (Post-EISA) (d)
	1,100-1,300	150	72
	650-1,099	100	72
	575-649	75	53
500-699	500-574	60	43
300-499	350-499	40	29
150-299	250-349	25	25
90-149		15	15
70-89		10	10

In addition, evaluators should calculate baseline wattage for each lamp in the tracking database. Therefore, an evaluator will calibrate the total estimated delta watts to the actual type and number of measures sold or distributed through the program.

Bulbs expected to be in use in 2020 and beyond will be affected by the EISA backstop provision mentioned in Section 1. The life-cycle savings of CFLs, therefore, should terminate for any remaining years in the expected useful life beginning in mid-2020, and the life-cycle savings for LEDs should incorporate this upcoming baseline change.²⁰

4.5 Replacement of Efficient-Lighting Products With Newer Efficient-Lighting Products

The previously discussed methodology assumes that at the time of measure failure, the consumer has the choice of installing an energy-efficient lighting product or a standard-efficiency lighting product, regardless of what was previously installed. In areas with a long history of CFL promotion—and as market penetration increases for CFLs or other high-efficiency lighting products—there is a higher probability that consumers are using some fraction of the energy-efficient lighting products distributed through programs to replace installed CFLs that fail.

There are two approaches commonly used to address this issue. To avoid underestimating program savings, the Residential Lighting Evaluation Protocol recommends that evaluators apply only one of these adjustments:

¹⁹ Bulb shapes that fit into this category are B, BA, C, CA, DC, F, and G lamp shapes

²⁰ For example, a CFL sold/installed in 2014 that has an eight year expected useful life could claim savings for the first six years (through 2019), then zero savings for the final two years of the expected useful life.

- ***Least Efficient Baseline Approach.*** To determine gross savings, assume the baseline is the least efficient product available with equivalent lumen output (e.g. EISA compliant halogen), even if the customer previously had a CFL or LED installed in the socket. With this approach, customers installing efficient lamps in sockets previously occupied by similarly efficient lamps would be handled under investigation of program attribution. (Nexus Market Research, Inc. et al. 2009).²¹
- ***Market Saturation Baseline Approach.*** Revise the baseline wattage assumptions to reflect the share of in-kind replacement of efficient lamps. This approach requires the collection of data on the proportion of high-efficiency lamps distributed through the program that are replacing existing CFLs. This approach is an alternative way to capture attribution, as customers with CFLs are presumably those that are also most likely to be free riders and replace an efficient bulb with another efficient bulb.

As more efficiency programs promote LEDs, further research will be required to investigate the likelihood that energy-efficiency minded consumers are replacing CFLs with LEDs.

4.6 Uncertainty Regarding the Baseline and the Need for Ongoing Research

The recommended Residential Lighting Evaluation Protocol acknowledges continued uncertainties around the residential lighting market in the next few years. These uncertainties deal with the types and prices of lighting products that will be available on the market. Another source of uncertainty is consumer reactions to the requirements and new products, which includes behaviors such as product hoarding, “bin jumping” to different incandescent wattage levels, and how quickly retailers sell through the existing product inventories. The uncertainty around EISA was further heightened in December 2011 with the passage of the fiscal year (FY) 2012 omnibus spending bill, which included a rider that halted funding for the U.S. Department of Energy to enforce the new standards.²² The National Electrical Manufacturers Association (NEMA), representing more than 95% of the U.S. lighting manufacturing industry, issued a press release after the passage of the bill stating that they did not support it. NEMA also pointed out that American manufacturers have invested millions of dollars in transitioning to energy-efficient lighting, and EISA gave state attorney generals the authority to enforce the standards.

Thus, in cases where actual pre-program measure wattage is not available, the Residential Lighting Evaluation Protocol recommends that evaluators continue to adopt the EISA standards as the new baseline. However, program administrators who have adequate resources should

²¹ The New England *Residential Lighting Markdown Impact Evaluation*, January 20, 2009 found that 43% of respondents (24 out of 56) stated that the CFLs recently purchased and not installed were intended for use to replace incandescent lighting. That is, 57% of the respondents intended to use the stored CFLs to replace existing CFLs when they failed. While evaluators used this to discount the delta watts, if those respondents who are already intending to replace CFLs with CFLs are presumably counted as freeriders, then program attribution should already incorporate any necessary adjustments.

²² This rider has been extended in subsequent resolutions including the fiscal year 2013 budget appropriations.

conduct ongoing monitoring and research to determine whether the delta watts assumptions reflect actual market conditions during the phase-in of the EISA requirements and use a lagged approach to phasing in the requirements. For example, after conducting shelf stocking studies for several Massachusetts program administrators, evaluators implemented a time-dependent, shifting baseline.²³ This approach incorporated data showing that consumers in the territory were: (1) purchasing incandescent bulbs subsequent to a six-month phase-in period, and (2) purchasing EISA-compliant halogens prior to the EISA implementation date.

Consequently, program administrators should measure the extent of these effects before deviating from the recommended six-month sell-through period. In particular, research in California—where the standards take effect one year in advance of the rest of the United States—may be informative for determining retailer and manufacturer reactions to EISA.

4.7 Annual Operating Hours

Hours of use (HOU) represents the estimated hours per year that consumers will use the energy-efficient lighting product. Recent studies have shown that the estimated average HOU for CFLs range from a low of 1.5 to a high of 3.0 hours per day (see Table 4). Myriad factors affect the expected number of hours that consumers use energy-efficient lighting products per year, including differences in demographics, housing types and vintages, CFL saturation, room type, electricity pricing, annual days of sunshine, and even an “urban canyon” effect. As a result, extrapolation of data from one region to another has not proven successful for accounting for these influencing factors (Navigant Consulting and Cadmus Group, Inc. 2011).²⁴ If extrapolation must be done (due to recently launching a program or there are not sufficient resources to conduct a metering study) evaluators may use secondary data from other metering studies (discussed in greater detail in Section 4.9). Based on these disparate results, this protocol recommends that program administrators collect primary data through a metering study of residential lighting measures.

²³ See *Residential Lighting Shelf Survey and Pricing Analysis* (June 8, 2013), by The Cadmus Group and NMR

²⁴ For example, Cadmus’ analysis of metered CFL hours of use, conducted as part of the evaluation of 2010 EmPOWER Maryland Residential Lighting and Appliances Program, revealed a significant difference in average daily hours of use as compared to extrapolating the hours of use from the ANCOVA model developed as part of the evaluation of the 2006-2008 California Upstream Lighting Program.

Table 4. Estimated CFL Hours of Use from Recent Metering Studies

Region	Publication Year	Author	Sample Size (Homes)	# of Efficient Bulbs Metered	Estimated Average Daily HOU
California (PG&E, SCE, and SDG&E service areas)	2010	KEMA, Inc. (KEMA, Inc. and The Cadmus Group, Inc. 2010)	≈1,200	N/A	1.9
Georgia (Georgia Power Company)	2013	Nexant and Apex Analytics LLC	125	594	2.8
Massachusetts, Rhode Island, Vermont, Connecticut	2009	Nexus Market Research, Inc. et al. (Nexus Market Research, Inc. et al. 2009)	157	657	2.8
Massachusetts, Rhode Island, Connecticut, New York	2014	NMR Group and DNV GL (2014)	848	5,730*	2.9 (Efficient bulbs) 2.7 (All bulbs)
Illinois	2012	Navigant Consulting	67	527	2.7
North Carolina (Duke Energy Progress)	2012	Navigant Consulting, Apex Analytics LLC	100	413	2.9
Maryland (EmPOWER)	2011	The Cadmus Group, Inc., and Navigant Consulting (Navigant Consulting and The Cadmus Group, Inc. 2011)	61	222	3.0
North Carolina, South Carolina	2011	TecMarket Works and Building Metrics (TecMarket Works and Building Metrics 2011)	34	156	2.5 (North Carolina) 2.7 (South Carolina)
Ohio	2010	Vermont Energy Investment Corporation (from Duke Energy)	N/A	N/A	2.8
Pacific Northwest	2010	Northwest Regional Technical Forum, based on CA, 2010 KEMA, Inc.	N/A	N/A	1.9 for existing homes, 1.5 for new homes

*Note the sample included sockets with standard and efficient bulbs. In addition, separate HOU were also estimated for Manhattan and downstate New York (with HOU for efficient bulbs estimated at 3.7).

4.8 Metered Data Collection Method

Base metering on the following factors and associated guidelines:

- Logger type
- Length of metering period
- Information collected on site
- Data integrity

4.8.1 Logger Type

This protocol recommends change-of-state loggers over periodic readings for standard bulbs because they can capture short intervals and switch rates (the number of times lights are turned on and off). For dimmable and three-way bulbs, the protocol recommends using light intensity loggers. In addition, current-sensing meters (rather than light-sensing meters) are an effective approach for outdoor conditions in which ambient light can potentially inflate the estimated hours of use.

4.8.2 Length of Metering Period

The length of the metering period is dependent on the focus of and available resources for the study. For example:

- If the intent of the study is to measure energy usage *without* concern for estimating summer peak demand (coincidence factor), then use limited metering period. Evaluators can limit the metering period to several weeks before and after the equinox (spring or fall). The general premise supporting annualizing metering periods shorter than one year is that the annual average use occurs precisely on the equinox; in fact, the equinox represents the annualization equation's intercept. A 2013 study demonstrated the precision of relying on a short period surrounding the equinox relative to using a complete 12 months of metering data.²⁵
- If the metering study in question is concerned *with both energy and demand*, then conduct logging for at least six months and capture summer, winter, and at least one shoulder season—fall or spring. Ideally, evaluators should install loggers immediately preceding either the summer or winter solstice in order to capture a complete six months of data. In this case, an annualization adjustment is not required. If the metering period is less than six months *and* the meter placement is not coincident with the solstice, then annualize the data—using techniques such as sinusoidal modeling—to reflect a full year of usage.²⁶

²⁵ Shepherd, B.; Rambo, E.; Busker, M. (2013) *Annualization of Results of Residential Lighting Meter Data*, presented at 2013 International Energy Program Evaluation Conference, August 2013, Chicago, IL.

²⁶ Sinusoidal modeling assumes that hours of use will vary inversely with hours of daylight over the course of a year. Sinusoid modeling shows that: (1) hours of use change by season, reflective of

4.8.3 Information Collected On Site

Conduct in-home lighting audits at all homes participating in the metering study. To allow for an estimate of saturation of high-efficiency lighting equipment, it is highly recommended that the auditors record the number and type of high-efficiency lighting products by fixture and room type and conduct a full inventory of sockets. In addition, evaluators should collect on-site information specifically related to the logger placements that details room type, window orientation, fixture type, notes about possible ambient light issues, etc.

4.8.4 Data Integrity

Clean and thoroughly check all metered data for errant and erroneous observations. For example, at the moments of installation and removal, clip the downloaded data to eliminate extraneous readings. Also, omit data from broken loggers or loggers removed by residents. Also omit data from loggers suspected to have metered daylight/ambient light. Finally, examine the data for “flicker” (that is, very frequent on/off cycling) and clean the raw data to correct for flicker. Evaluators can perform computer programming via R, SAS, or other statistical software that allows data from flickering bulbs to effectively remain on for the duration of the flickering event, rather than appear to be repeated on/off events.

4.8.5 Metering Sample Design

Ideally, evaluators should conduct metering for large samples of all major lighting types (including incandescent baseline lamps and fixtures); however, in practice, most evaluations do not have adequate resources for a scope of this size. Consequently, to optimize the allocation of moderate evaluation resources, it is important to target the metering to select lighting measures—typically CFLs—that represent the majority of savings in a residential lighting program. (This is especially true for retrospective program savings.)

Where savings are used prospectively, it is important to attempt to meter all lighting types, as recent studies have found that efficient bulbs have higher hours of use than do average bulb types.²⁷

For measures representing a small percentage of savings (such as LEDs in more recent programs), estimate the overall HOU by examining the CFL hours of use for similar rooms and fixture types.

Given the difficulty of identifying program bulbs in an upstream program, field technicians may place loggers on energy-efficient bulbs in a random sample of homes that have installed similar

changes in the number of daylight hours and weather; and (2) these patterns will be consistent year to year, in the pattern of a sine wave. An example of this approach is provided in the evaluation of the 2006-2008 California Upstream Lighting Program evaluation.

²⁷ For example, a forthcoming lighting metering study from New England estimated daily hours of use for all bulbs at 2.7 hours/day, but 3.0 hours/day for efficient bulbs. Note, however, the study does not believe this difference is due to saturation, but rather to a combination of selective installation (i.e., higher use sockets) and potentially also due to snapback.

measures, even if those measures are not definitely known to be part of a mark-down or buy-down program. For homes that have many energy-efficient lighting products, evaluators may meter a subsample of fixtures, so long as they are selected randomly within the home. For example, if a home has CFLs in 10 fixtures, place meters on three to five randomly selected fixtures.²⁸ This will both minimize the invasiveness in homes that are highly saturated with energy-efficient lighting products and be cost-effective, enabling metering of a larger sample of sockets in an equivalent number of homes.

Determine the total number of loggers installed based on the desired levels of statistical confidence and precision, assuming a coefficient of variation (CV) based on recent studies of programs with similar CFL saturation (using the maturity of program as a proxy, if necessary) and housing characteristics (The Cadmus Group, Inc. 2010) (Navigant Consulting and Cadmus Group, Inc. 2011).²⁹ Historically, the CV has been assumed (and sometimes reported) as approximately 0.5 or 0.6. However, this CV may be considerably too low when accounting for the serial correlation of usage (and error) across light circuits within a home.

A forthcoming lighting hours-of-use study from New England, based on over 800 homes and 5,700 loggers, recommends that evaluators utilize a CV of at least 1.2 for each area of interest (each room type or each subgroup in the population). To ensure an adequate sample size, the CV may be as high as 1.5.

This Residential Lighting Evaluation Protocol recommends that, at a minimum, room type be considered as a subsample, since room type is one of the most important determinants of hours of use. Therefore, the program administrator should work with the program evaluator to establish well-defined targets for the total number of room types to meter. Subsampling by room types (rather than by home type) allows for a potentially more homogeneous population unit because of more consistent usage within room types rather than across homes.

When calculating the HOU from the meter data collected, the precision estimates should take into account both the primary sampling unit (household) and other subsample units (room type). Most statistical packages used for HOU estimation allow for clustering of the sampling unit (household) to account for correlation.

²⁸ A number of studies, including the evaluation of the California Upstream Lighting Program, provide publicly available examples of how to randomly select fixtures for metering.

²⁹ A forthcoming lighting hours-of-use study from New England recommends that evaluators utilize a CV of at least 1.2 for each area of interest (that is, each room type or each subgroup in the population) and possibly as high as 1.5 to ensure an adequate sample size. If sampling very specific room types or subgroups, the CV may need to be even greater.

The confidence and precision of the HOU estimate is not simply a factor of usage across each hour for each logger. Using these units would lead to grossly overestimated precision, if based on every hour across the metering period. Furthermore, the evaluator's calculations should not ignore the error inherent in the HOU from an annualization model. Rather, when estimating the overall HOU, any evaluator's model or calculation should estimate the annualized HOU for each logger across all hours, account for the error from this model, and then use these estimates as the starting point for the room-based and household-based averages.

Following the metering effort and the annualization of results, compare the distribution of loggers by room type to the actual distribution of energy-efficient lighting products per room type, as noted at the time of the audit. Then weight the HOU s to reflect the actual distribution of lighting products by room type. For example, if 10% of the loggers are installed in kitchen fixtures, but the audit data reveal that 15% of all CFLs are installed in kitchens, weight the data from the loggers in kitchens up by 1.5 when calculating total HOU.

It is also important to estimate the HOU by room type since direct-install programs often target higher use fixtures and sockets in higher use rooms. If administrators of these programs track the room types associated with the installation of efficient lighting products, evaluators can then base HOU on room type.

In addition, evaluators should compare the demographic and household characteristics of the metering sample with the characteristics of the total population of homes believed to have purchased energy-efficient lighting products. (Evaluators can collect this information through telephone surveys.) If significant differences appear *and* there is a large enough sample to support reweighting based on such characteristics, evaluators should weight the results to reflect these differences.

4.9 Using Secondary Data

While metering is the recommended approach, program administrators who are just launching a program—or who do not have sufficient resources to conduct a metering study—may use secondary data from other metering studies.³⁰ This protocol recommends using the following criteria when selecting and using secondary data to estimate HOU:

- Similarities in service territories
- Appropriate sample size
- Length of metering period
- Adjustments to reflect hours of use by room type

³⁰ As discussed in *Considering Resource Constraints* in the “Introduction” chapter to this UMP report, small utilities (as defined under the U.S. Small Business Administration [SBA] regulations) may face additional constraints in undertaking this protocol. Therefore, alternative methodologies should be considered for such utilities.

4.9.1 Similarities in Service Territories

Selecting a similar service territory based on geographic proximity and as many common demographic and household characteristics as possible will increase the likelihood that the secondary data provide a valid, reasonable, and accurate estimate.

4.9.2 Sample Size

The number of observations varies considerably between studies, so evaluators should compare the sample size, standard errors, and precision levels at equivalent confidence levels across studies.

4.9.3 Length of Metering Period

The protocol recommend conducting studies that capture both winter and summer usage to estimate overall annual use.

4.9.4 Adjustments to Reflect Hours of Use by Room Type

To extrapolate hours of use from one region to another, one approach is to calibrate the hours of use based on the efficient bulb saturation by room type. If possible, weight the HOU by room type from a secondary data source s by the room type distribution of efficient lighting for the region under study.

4.10 Snapback/Rebound or Conservation Effect

“Snapback” or “rebound” refers to changes in use patterns that occur after the installation of an energy-efficient product, resulting in reducing the overall measure savings. For example, when residential lighting customers use a CFL for more hours per day than they used the replaced incandescent bulb, this constitutes snapback. This behavior change may be due to factors such as the cost savings per unit of time from the CFL or a concern that turning CFLs on and off shortens their effective useful life (although it is unlikely most consumers are aware of this effect on bulb life). Some customers, however, might have lower hours of use after installing a CFL, perhaps due to a corresponding desire to reduce energy consumption or dissatisfaction with the quality of light.

Due to the nature of residential lighting programs, it is not typically possible to conduct metering both before and after the installation of energy-efficient lighting. However, a recent lighting study in the Northeast found that the hours of use were greater for sockets with efficient bulbs compared to all sockets in the house (NMR Group 2014). The difference was believed to be either due to: 1) differential socket selection (households selecting higher-use locations for their high-efficiency light bulbs); 2) Shifting usage (households install an efficient bulb in a socket and then begin to use that socket in lieu of sockets containing inefficient bulbs); and 3) snapback. However, this evaluation did not collect any data to determine which of these three theories is correct, or the proportion of the difference between efficient and inefficient HOU that is attributable to each type of behavior. Therefore, the Residential Lighting Protocol recommends researching for snapback/rebound effects in future HOU estimates.

4.11 In-Service Rate

The in-service rate (ISR) represents the percentage of incented residential lighting products that are ultimately installed by program participants. ISRs vary substantially based on the program delivery mechanism, but they are particularly important in giveaway or upstream programs where the customer is responsible for installation.

For the upstream programs shown in Table 5, three factors have led to first-year, in-service rates well below 100%: (1) the often deeply discounted price, (2) the inclusion of program multipacks, and (3) the common practice among consumers of waiting until a bulb burns out before replacing it.

Table 5. Estimated First-Year, In-Service Rates from Recent Evaluations of CFL Upstream Lighting Programs

Region	Publication Year	Author	Percentage of CFLs Installed the First Year After Purchase*
Connecticut, Massachusetts, Rhode Island, Vermont	2009	Nexus Market Research Inc., et al.	76%
North and South Carolina	2013	Navigant Consulting and Apex Analytics	79%
Illinois	2013	Navigant Consulting	72% / 82% (standard/specialty)

*Based on program year only, not years subsequent to the program year or several years in a multiyear program cycle.

The Residential Lighting Protocol recommends evaluators estimate in-service rates using the methods appropriate to the specific delivery mechanism:

- For ***direct-install programs***, conduct verification (such as telephone survey or site visits) to assess installation and early removal (that is, removal prior to failure).
- For ***giveaway or coupon programs***, conduct verification when customer contact information is available. Also, ask respondents whether the installation location was within the relevant service territory, and the measure was installed in a home or business. If the installation was in a business, ask about the type of business.

If customer information is not available, rely on either secondary data (such as that from a similar program where customer information was collected) or on the in-home audit approach (described in the next bullet).

- For ***upstream programs***, calculate in-service rates through an in-home audit. Because program bulbs cannot be easily identified, evaluators can calculate the in-service rate as the number of installed bulbs purchased in a recent 12-month period divided by the total number of bulbs purchased in the same 12-month period. If the sample size of homes with bulbs purchased in the recent 12-month period is insufficient to provide the necessary levels of confidence and precision, apply a long-term, in-service rate using all bulbs, regardless of the time of purchase.
- Although the in-home audit is the recommended approach, evaluators can use a telephone survey when program administrators are just ***launching a program or do not have sufficient resources*** to conduct an in-home audit. To minimize recall bias, the callers should focus questions only on products purchased in the recent 12-month period rather than the period covering the long-term, in-service rate. (Studies have shown that respondents tend to have better recall about the percentage of bulbs

purchased and installed within the past 12 months, as compared to the percentage of bulbs the consumer has ever been purchased and installed.)

Although first-year, in-service rates for upstream programs are less than 100%, recent studies have demonstrated that consumers plan to install most of the incented bulbs; however, they sometimes wait until an existing bulb burns out.³¹ As a result, for savings that occur in years following the year that the incentive was paid, program administrators have been able to take credit in one of these ways:³²

- ***Discount Future Savings.*** In this method, all of the costs and benefits are claimed during the program year, but the savings (in terms of avoided costs, kWh, or kW) from the expected future installation of stored program bulbs are discounted back to the program year using a societal or utility discount rate.³³
- ***Stagger Timing of Savings Claims.*** In this method, all of the expenses are claimed during the program year, but the savings (and, therefore, the accompanying avoided-cost benefits) are claimed in the years in which the program measures are estimated to be installed.

To calculate the installation rate trajectories, the Residential Lighting Evaluation Protocol recommends using the findings from the 2013 Duke Energy Progress (DEP) Installation Rate Trajectory Study, which determined that 93.6% of CFLs are installed within three years of purchase. In contrast to previous studies, the DEP study examined actual bulb installations for a period of one year, with on-site verifications conducted three times over the course of the study and a self-reported light bulb storage log updated on a monthly basis.

The DEP study found that 79% of CFLs are installed within 12 months of purchase (Year 1), 87.7% of CFLs are installed within 24 months of purchase (Year 2), and 96.3% are installed within 36 months of purchase (Year 3). Stated another way, an additional 14.6% of CFLs from the original total (or 69.5% of those remaining in storage) were installed within three years of purchase. Due to the small sample size of bulbs that were still in storage more than three years after purchase, the DEP evaluation team did not estimate ISR for bulbs installed in Year 4 or beyond.

³¹ For example, the evaluation of the Program Year 2 Commonwealth Edison Residential ENERGY STAR Lighting Program found that about 90% of customers with CFLs in storage were waiting until a working incandescent or CFL burned out before they installed the stored CFLs (Table 3-6).

³² The selection of which approach will depend upon the study purpose and regulatory requirements.

³³ Note that while energy or demand savings are not normally discounted, this approach provides simplicity for calculating program benefit/cost ratios and the actual net present value of avoided costs, which often are used for cost recovery. For programs that want to bid into capacity markets (for example, PJM), the staggered approach is recommended since it more accurately captures the actual timing and cumulatively increasing nature of the demand savings.

Evaluators can follow this trajectory and calibrate to individual service territories using the methodology below. As outlined in

Table 6, program administrators use their researched value for their Year 1 ISR (ISR_{YR1}) and determine the ISR for subsequent years using the following methods:

- Year 2 ISR (ISR_{YR2}) is calculated by multiplying the ISR_{YR1} by 1.11.
- Year 3 ISR (ISR_{YR3}) is calculated by multiplying the ISR_{YR2} by 1.067.
- Year 4 ISR is calculated as the midpoint between ISR_{YR3} and 99%, or $ISR_{YR4} = (99\% + ISR_{YR3}) / 2$. As a four-year installation rate could not be estimated in the DEP study, the Residential Lighting Evaluation Protocol recommends using a blended value of ISR_{YR3} , and the 06-08 CPUC Residential Retrofit three year ISR estimate of 99%.

Table 6. Estimated Three-Year In-Service Rate Calculations

Year	Cumulative Installed Percentage	Example Results*
Year 1	Researched Value	79.0%
Year 2	$ISR_{YR1} * (1.11)$	87.7%
Year 3	$ISR_{YR2} * (1.067)$	93.6%
Year 4	$(99\% + ISR_{YR3}) / 2$	96.3%

*Based on 2013 DEP installation rate study. This rate represents the percentage of bulbs purchased in Year 1 and installed by the end of each following year

As noted in the delta watts discussion, this methodology does not adjust for CFL-to-CFL replacement, which will likely be handled during assessments of program attribution.

4.12 Interactive Effects With Heating, Ventilating, and Cooling

CFLs and LED lamps give off less waste heat than incandescent bulbs, which affects heating, ventilating, and cooling (HVAC) energy requirements. These effects vary based on space conditioning mode, saturation of space heating and cooling technologies and their relative efficiencies, and climate zones. The influence of climate zone on interactive effects depends on a variety of house-specific factors.

Taking all of these factors into account, the net impact on lighting energy cost savings could be positive, negative, or neutral (Parekh et al. 2005; Parekh 2008). In cooling-dominated climates, the interactive effects are positive, resulting in additional savings due to decreased cooling load. However, in heating-dominated climates, the interactive effects are negative, with decreased savings due to increased heating load.

Because of the potential impacts of interactive effects, the Residential Lighting Evaluation Protocol recommends including these effects in evaluations of residential lighting programs.³⁴ One common approach is to estimate these effects through the use of simulation models, examining a mix of typical housing types (such as different vintages) and reflecting the estimated saturation, fuel shares, and size/efficiency of HVAC equipment. (That is, the percentage of homes that have air-conditioning or electric versus gas heat.) If necessary, use secondary sources—such as the Residential Energy Consumption Study (RECS) — to estimate these inputs. A 2010 study used another approach that entailed conducting a billing analysis (Brunner et al. 2010).

Some regions have developed interactive effects calculators based on such simulations (for example, in California, the Database for Energy Efficiency Resources (DEER)³⁵ and the Regional Technical Forum (RTF) in the Northwest. Such regional collaboration can minimize the cost of determining the interactive effects for those regions that do not already have such a tool.

If regional collaboration is not an option *and* the program administrator does not have the resources to complete the simulations, the Residential Lighting Evaluation Protocol recommends using a value from an existing resource. It is recommended that the value used reflects key similarities between the program administrator's territory and the territory from which the data are taken. At a minimum, these key similarities should be the climate (heating and cooling degree days and, ideally, the latitude), HVAC system types, and HVAC system saturations.

³⁴ Note that interactive effects are only relevant for bulbs installed in conditioned spaces. Thus, exterior lights will not have HVAC interactive effects.)

³⁵ www.deeresources.com/DEER2011/download/LightingHVACInteractiveEffects_13Dec2011.xls

5 Other Evaluation Issues

The incentive structure of upstream lighting programs does not inherently allow for assurances that each purchaser of a program bulb is a residential customer in the sponsoring program administrator's service territory. Therefore, some program bulbs may be purchased by nonresidential customers or to customers served by other utilities. This section discusses these parameters.

5.1 Cross-Customer Class Sales

Nonresidential customers typically use lighting products for more hours per day than do residential customers. Typically, nonresidential customers also have higher peak coincidence factors. Therefore, the lighting products that are incentivized through a residential lighting program but installed in nonresidential sockets may lead to higher savings than those assumed through the previously discussed methods.

The typical approach evaluators use to estimate this parameter is through customer intercept surveys, where, at the time of sale, customers who purchase lighting products participate in a short survey about intended installation location and facility type. Evaluators also estimate this parameter through surveys with store managers (asking them to estimate the percentage of bulbs sold to nonresidential customers), residential customers (asking them if they purchased discounted lighting products and installed them in businesses), or with the owners of small businesses (asking them where they typically purchase lighting products).

The Residential Lighting Evaluation Protocol recognizes these key limitations in estimating this parameter:

- ***Customer intercepts may not represent all program sales.*** Conducting customer intercept surveys can be expensive, and they are typically conducted only in high-volume stores (such as Home Depot, Lowe's, and Walmart). In some cases, these surveys are conducted only during high-volume promotions. Also, because some retailers refuse to allow the surveys on their premises, the surveys conducted for a program may not be representative of total sales.

Accuracy from intercepts is further challenged because business owners and contractors: (1) may be a minority of purchasers, (2) may purchase more units per visit than residential purchasers, and (3) may not purchase during the same time as the average residential purchaser.
- ***Surveys lack high reliability.*** Store managers usually do not have detailed information on program bulb purchasers, so their estimates of sales to non-residential customers may be unreliable. There are also challenges when surveying of small business customers, such as nonresponse bias (that is, calling a small business and not getting cooperation from the business decision maker to take a survey). Additionally, because of recall bias occurring among survey participants, quantifying the number and type of bulbs purchased by channel may be difficult.

5.2 Cross-Service Area Sales (Leakage)

Recent studies have also attempted to estimate the number of program bulbs sold to customers outside of the program administrator's service territory. This is commonly referred to as "leakage" or "spillage."

The most common approaches to determining leakage have been clearly delineated in Arkansas³⁶, and they are cited here in order of preference.

- ***Customer Intercept Surveys.*** This is the preferred method due to primary data collection for actual participants, although it can be very difficult to receive permission from participating retailers. The sampling strategy used should assure a random mix of entities (geographic, retailer, day of week, and avoiding promotional events only).
- ***Geo-mapping with general population surveys.*** This method involves modelling leakage scores based on the geographic proximity of participating retailers to sponsoring utility customers relative to other utility customers (non-sponsoring). Refine the model by using general population telephone surveys for confirmation of purchasing behavior for both sponsoring and non-sponsoring utilities in the region.
- ***Opt-in Surveys.*** This involves including label or note with each incented product among all participating retailers on how to participate in survey. (Ideally, the survey should be multimodal: reply card, online, and phone number.) Low response rates and non-response bias are drawbacks.

This protocol recognizes these key limitations in estimating leakage:

- ***Cross-Region Sales.*** Many neighboring service territories are now targeted by residential lighting programs; thus, there is less of an incentive to shop outside one's own service territory to purchase less-expensive lighting products. In some cases, the leakage of program bulbs occurs in both directions across service boundaries, which may offset the effect in either or both territories.
- ***Many programs now limit the number of participating retailers, so that leakage is minimized.*** Many program administrators now require retailers participating in upstream programs to be located far enough within the service territory or to be surrounded by a certain percentage of population of program customers, so as to minimize potential leakage.

5.3 Estimating Cross-Customer Class and Cross-Service Area Sales

In addition to the limitations presented above, these parameters may also at least partially offset each other. (That is, the increased savings of sales to non-residential customers may be at least

³⁶ Arkansas2013 Technical Reference Manual, Protocol K: Leakage

partially offset by leakage.)³⁷ Given this, it is reasonable to exclude these parameter estimates from impact evaluations of upstream residential lighting programs. In addition, given the opposing directions of these parameters, either both – or none – of these parameters should be incorporated. Thus, do not claim increased savings due to sales to business customers without also adjusting for leakage, and do not decrement program savings due to leakage without also incorporating sales to business customers.³⁸

³⁷ Note that these protocols do not imply that these effects will be exactly offsetting, only that they work in opposite directions: sales to non-residential customers will typically lead to greater savings, and cross-service area sales will lead to lower savings in the sponsor's service territory.

³⁸ Note that exceptions can be made in cases where program administrators are surrounded by other service territories offering similar programs. In these cases, sales to business customers can be claimed without reducing sales due to leakage. An example of this is in Pennsylvania where the Phase II Evaluation Framework recommends that evaluation contractors assume that leakage into and out of each utility territory effectively offsets each other since they offer the same or similar upstream lighting programs.

6 Program Evaluation Elements

Residential lighting programs offer a range of measures through multiple delivery strategies, with the upstream CFL programs currently being the most ubiquitous. Program administrators who offer a variety of measures and rely on multiple delivery strategies may need to prioritize their evaluation resources based on criteria such as contribution to savings and assessed uncertainty. Evaluators should assess savings through a mix of primary and secondary data, using IPMVP Option A (Retrofit Isolation: Key Parameter Estimates).

A key area that needs additional research involves the assumptions regarding baseline wattage as EISA standards take effect and as LEDs become a larger source of program savings. For example, in absence of the program: *What is the percentage of customers who would have installed a CFL, rather than a program-incented LED?*

In addition, the recent lighting HOU study from the Northeast found that hours of use were greater for sockets with efficient bulbs compared to all sockets in the house (NMR Group 2014). More research is needed to determine if this difference is due to differential socket selection, shifting usage, snapback, or some combination of these three factors.

7 References

Brunner, E.J.; Ford, P.S.; McNulty, M.A.; Thayer, M.A. (2010). “Compact Fluorescent Lighting and Residential Natural Gas Consumption: Testing for Interactive Effects.” *Energy Policy*. (38:3); pp. 1288-1296. <http://www.sciencedirect.com/science/article/pii/S0301421509008313>.

Cadmus Group, Inc. (December 2010). *Lighting and Appliance Evaluation—PY 2*. Prepared for Ameren Illinois.

Cadmus Group, Inc and NMR Group, Inc. (June 8, 2013). *Residential Lighting Shelf Survey and Pricing Analysis, Final Report*. Prepared for Cape Light Compact, National Grid, NSTAR Electric, Unitil, Western Massachusetts Electric Company, and Energy Efficiency Advisory Council Consultants.

KEMA, Inc. and Cadmus Group, Inc. (February 8, 2010). *Final Evaluation Report: Upstream Lighting Program*. Prepared for California Public Utilities Commission, Energy Division. www.calmac.org/publications/FinalUpstreamLightingEvaluationReport_Vol2_CALMAC.pdf.

KEMA, Inc. (February 25, 2005). *CFL Metering Study*. Prepared for California’s Investor-Owned Utilities (Pacific Gas and Electric Company [PG&E], Southern California Edison [SCE], and San Diego Gas and Electric [SDG&E]).

Navigant Consulting and Apex Analytics, LLC. (November 7, 2013). *Storage Log Study of CFL Installation Rate Trajectory*. Prepared for Duke Energy Progress.

Navigant Consulting and Apex Analytics, LLC. (September 5, 2012). *Preliminary Shelf-Stocking Study Results for the Residential ENERGY STAR Lighting Program*. Prepared for Progress Energy Carolinas.

Navigant Consulting and Cadmus Group, Inc. (January 15, 2011). *EmPOWER Maryland 2010 Interim Evaluation Report*. Prepared for Baltimore Gas and Electric, Potomac Electric Power Company, Delmarva Power and Light (DPL), Southern Maryland Electric Cooperative (SMECO), and Allegheny Power (AP).

Navigant Consulting, Cadmus Group, Inc, and Apex Analytics LLC. (June 27, 2012). *EM&V Report for the 2010-2011 Residential Energy Star Lighting Program*. Prepared for Duke / Progress Energy Carolinas

Nexant, Inc and Apex Analytics LLC. (October 4, 2013). *Georgia Power Company Residential Lighting Saturation and Metering Study*. Prepared for Georgia Power Company.

Nexus Market Research, Inc. and RLW Analytics, Inc. (October 2004). *Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs*. Prepared for The Cape Light Compact, State of Vermont Public Service Department for Efficiency Vermont, National Grid, Northeast Utilities, NSTAR Electric, Unitil Energy Systems, Inc.

Nexus Market Research, Inc., RLW Analytics, Inc., and GDS Associates. (January 20, 2009). *Residential Lighting Markdown Impact Evaluation*. Prepared for Markdown and Buydown Program Sponsors in Connecticut, Massachusetts, Rhode Island, and Vermont.
www.env.state.ma.us/dpu/docs/electric/09-64/12409nstrd2ae.pdf.

NMR Group, DNV GL (May 5, 2014). *Northeast Residential Lighting Hours-of-Use Study*. Prepared for Connecticut Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid Massachusetts, National Grid Rhode Island, New York State Energy Research and Development Authority.

Parekh, A.; Swinton, M.C.; Szadkowski, F.; Manning, M. (2005). *Benchmarking of Energy Savings Associated with Energy Efficient Lighting in Houses*. National Research Council Canada. NRCC-50874. <http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=shwart&index=an&req=20377557>.

Parekh, A. (2008). "Do CFLs Save Whole-House Energy?" *Home Energy Magazine*, November/December 2008. pp. 20-22.

TecMarket Works and Building Metrics. (February 15, 2011). *Duke Energy Residential Smart Saver CFL Program in North Carolina and South Carolina: Results of a Process and Impact Evaluation*.

Vermont Energy Investment Corporation. (August 6, 2010). *State of Ohio Energy Efficiency Technical Reference Manual*. Prepared for the Public Utilities Commission of Ohio.
http://amppartners.org/pdf/TRM_Appendix_E_2011.pdf.

Vermont Energy Investment Corporation. (July 2011). *Mid-Atlantic Technical Reference Manual, Version 2.0*. Facilitated and Managed by Northeast Energy Efficiency Partnerships.
http://neep.org/uploads/EMV%20Forum/EMV%20Products/A5_Mid_Atlantic_TRM_V2_FINAL.pdf.

8 Resources

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). (2000). *Research Project 1093 Compilation of Diversity Factors and Schedules for Energy and Cooling Load Calculations*. ASHRAE Research Report.

ASHRAE. (2002). *Guideline 14-2002: Measurement of Energy and Demand Savings*.

ASHRAE. (2010). *Performance Measurement Protocols for Commercial Buildings*.

ASHRAE. (TBD). *Guideline 14-2002R* (Revision of *Guideline 14*, currently in process, publication date TBD).

Glacier Consulting. (March 6, 2008). *Analysis of Delta Watts Values for CFLs Rewarded Through the Residential Lighting Program During FY07*. Prepared for the State of Wisconsin Public Service Commission. www.cce1.org/eval/db_pdf/1215.pdf.

Evaluation Framework for Pennsylvania Act 129 Phase II Energy Efficiency and Conservation Programs (May 31, 2013). Prepared by the Statewide Evaluation Team: GDS Associates, Nexant, Research Into Action, and Apex Analytics.

Navigant Consulting and Itron. (December 21, 2010). *Plan Year 2 Evaluation Report: Residential ENERGY STAR Lighting*. Prepared for Commonwealth Edison Company.

PA Consulting Group and NMR Group. (April 22, 2010). *Focus on Energy Evaluation 2009 CFL Savings Analysis*.

RLW Analytics, Inc. and Nexus Market Research. (April 22, 2005). *Extended Residential Logging Results*. Prepared for National Grid.